LED Package and Luminaire Efficacy Evaluation for Emerging SSL Technologies

January 29, 2014

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Tracking LED Efficacy Progress

- **DOE has used current density (J, A/cm²) as the means by which LED efficacy (η) is tracked**

TABLE 4.1 PROGRESS PROJECTIONS FOR LED PACKAGE EFFICACY (LM/W)

Package Type	2012	2013	2015	2020	Goal
Cool-White (Color-mixed)	150	164	190	235	266
Cool-White (Phosphor)	147	157	173	192	199
Warm-White (Color-mixed)	113	129	162	224	266
Warm-White (Phosphor)	112	126	150	185	199

Notes:

1. Projections for cool-white packages assume CCT=4746-7040 K and CRI >70, while projections for warm- white packages assume CCT=2580-3710 K and CR I>80. All efficacy projections assume that packages are measured at 25 °C with a drive current density of 35 A/cm^2.

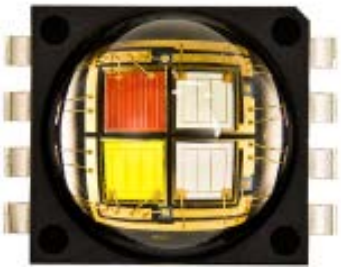
- **Good: all η results reported at same value of 35 A/cm²**
- **Not so good: J @ RT isn't relevant to many systems**

Package evolution requires new metric(s)

- **The proliferation of multi-chip, high-V packages requires detailed analysis of chip size, layout**

Chip sizes?
# of strings?
Serial?
Parallel?

- **DOE MYPP addresses "color mixed" hybrid chip packages, but evaluation of J becomes more complex in this case**
  - **Different chip types on different strings**

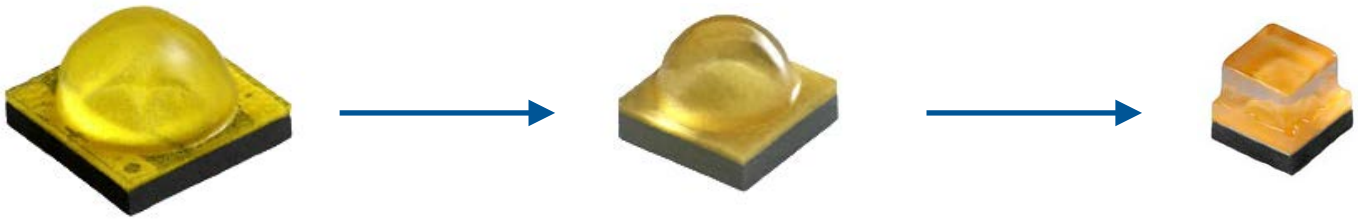


# of strings?
Chip sizes?
V_f / I_f combos

Package evolution requires new metric(s)

- **Consider combined power density: W/cm² or W/mm²**
  - *e.g.* **baseline: 1 W/mm² (~35 A/cm² for typical V_f)**
  - **Sum input powers of all chips/strings**

- **Use package substrate area or area under the lens instead of chip area?**
  - **Reflects trend of shrinking package sizes @ similar chip size**



➢ **Net effect: treat package as 'black box' that has electrical power in and optical/thermal power out**

  - *After all, this is what EQE addresses!*

Package evolution requires new metric(s)

- **Alternative: focus on $/LPW**
  - **Still "keeps manufacturers honest" if street prices are used**
  - **Recognizes falling chip costs & shrinking non-chip package BOM**

- **Complementary to DOE roadmap for $/klm:**

TABLE 2.4 SUMMARY OF LED PACKAGE PRICE AND PERFORMANCE PROJECTIONS

Metric	2012	2013	2015	2020	Goal
Cool-White Efficacy (lm/W)	150	164	190	235	266
Cool-White Price ($/klm)	6	4	2	0.7	0.5
Warm-White Efficacy (lm/W)	113	129	162	224	266
Warm-White Price ($/klm)	7.9	5.1	2.3	0.7	0.5

Note: Projections for cool-white packages assume CCT=4746-7040 K and CRI >70, while projections for warm-white packages assume CCT=2580-3710 K and CRI >80. All efficacy projections assume that packages are measured at 25 °C with a drive current density of 35 A/cm^2.

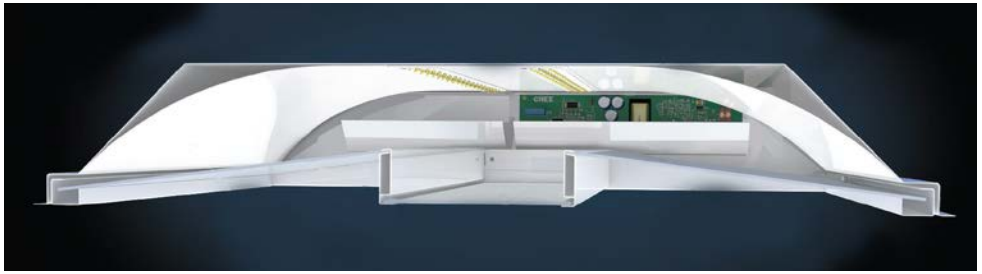
Component vs. System Efficacy

- **How "important" is component efficacy?**
  - **Depends on system requirements: space, optical, thermal, cost**

MR16

Small # of high-P packages @ high T

Troffer



Large # of low-P packages @ low T

- **In many cases: use more, cheaper, smaller packages at lower J**

- **<u>System</u> cost-normalized efficacy is the focus!**
  This is what the customer cares about, and it drives adoption

Summary

- **Current density @ RT is a useful, though limited, metric for LED efficacy evaluation**
- **Consider input power density as alternative, on either a chip or package area basis, at elevated T**
- **Focus on LED $/LPW, and how it serves system needs**
- **System normalized efficacy ($/LPW) is the focus, regardless of LED type or number**
  - **Customer doesn't care what's under the hood!**
  - **Cost-normalized efficacy is an adoption driver**